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IT'S OH-DARK THIRTY. DO YOU KNOW WHERE YOUR ENEMY IS? THE IMPORTANCE OF DATUMS WHEN LOCATING YOUR ENEMY

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The proper use of geographic coordinates (usually latitude, longitude and elevation) in combat operations is fundamental to mission success, especially on today?s modern battlefield. Yet recent history suggests the military has problems identifying, disseminating, and using geographic coordinates. Why is confusion with this crucial concept frequently the source of failure during warfare and how can we better prepare soldiers, sailors, airmen, and marines to eliminate confusion over geographic coordinates? A standard format for geographic coordinates which includes the datum to which they are referenced would eliminate problems with coordinates at all levels of the battlefield, from the command post to the front.

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Preface

The author wishes to thank his Faculty Research Advisor, Major Richard Shuff for the many hours he devoted to helping complete this paper.

Abstract

The proper use of geographic coordinates (usually latitude, longitude and elevation) in combat operations is fundamental to mission success, especially on today's modern battlefield. Yet recent history suggests the military has problems identifying, disseminating, and using geographic coordinates. Why is confusion with this crucial concept frequently the source of failure during warfare and how can we better prepare soldiers, sailors, airmen, and marines to eliminate confusion over geographic coordinates? A standard format for geographic coordinates which includes the datum to which they are referenced would eliminate problems with coordinates at all levels of the battlefield, from the command post to the front.

Chapter 1

Introduction

With whom lie the advantages derived from Heaven and Earth[1]

—Sun Tzu

There is perhaps nothing as important to warfare as an understanding of where you are and where your enemy is. Throughout history, this problem has caused field commanders to expend a great deal of effort during preparation for and conduct of war. This is true even to this day, especially since many modern weapon systems are targeted via computer using pre-programmed geographic coordinates at which the enemy's forces are thought to be located. Modern combat operations require a great deal of forethought and advance planning to ensure that friendly forces know where they are and where the enemy is located.

History is replete with examples where mistakes in locating one's enemy have had enormous consequences. In 1288 B.C., location of the enemy proved elusive to both sides. Ramses the Great was able to salvage a narrow victory after badly mislocating his opponent and suffering a surprise attack at the worst moment during his march.[2] In 1862, Maj Gen George McClellan suffered a number of setbacks, most notably during the Virginia Peninsula campaign, due to his inability to correctly locate and engage his enemy.[3] These problems have become more significant because increases in modern

weapon system range and accuracy have dramatically changed the way we use maps to support combat operations. Now, locating an opponent's army is not enough; each weapon and the crew manning it needs to know exactly where the enemy is since they often engage in warfare without seeing their foe.

To understand the impact a modern weapon system's range and accuracy has on requirements for mapping support, we must understand the complexities of mapping a three dimensional world on two-dimensional paper. By doing so, we will discover that merely providing geographic coordinates as a means of location is no longer sufficient. Knowledge of datums to which coordinates are referenced is fundamental to success in modern warfare.

Thesis

This study will focus on how the increased range of modern weapons now require geographic coordinates and information about datums for locating one's enemy. This study will not examine weapon systems' increasing requirements for more accurate geographic coordinates. Issues associated with accuracy are better kept for a future paper devoted to this one topic. After looking at how modern weapon systems increased range have driven changes to mapping support for combat operations, we will review recent United States military operations and examine how the use of geographic coordinates affect planning for and conduct of war. We will concentrate on a review of literature regarding lessons learned from the past operations which may not be receiving proper attention today given the success of fighting forces and weapon systems during Operation Desert Storm.[4] A review of Defense Mapping Agency (DMA) and current

Joint Staff documents will show that we must standardize guidance on the use of geographic coordinates.

Overview

The organization of this study will lead us through a process where we will:

1. Learn about advances in weapon systems and mapping support and potential confusion this may cause on the battlefield
2. Discuss recent combat operations and the use of geographic location references, focusing on how additional information is crucial to a modern geographic coordinate reference
3. Describe a standardized method for removing a source of confusion when handling geographic coordinates by including the datum to which the coordinates are referenced.

Notes

[1]Quoted in *The Art of War in World History*, edited by Gerard Chaliand, 222. Sun Tzu said he could forecast victory based on this and six other considerations.

[2]Dunnigan, James F., and Nofi, Albert A., *Victory and Deceit, Dirty Tricks at War*. New York, NY: William Morrow and Company, 1995, 27-29.

[3]Ibid., 116-118.

[4]Macy, Richard V. Air Combat Command, phone interview by author, 15 Jan 97.

Chapter 2

Modern Combat and Mapping Support

> *…[M]any key personnel within the Air Force, are generally either unaware of, or show little concern for, the vital significance of the geographic positions of launch sites and targets in the delivery of lethal weapons to a military target.*
>
> —Colonel B. B. Hunkapiller

In the not too distant past, warfare required each side to close within visual range of the enemy. The advent of long range artillery and airborne weapons soon allowed more distant engagement. During the two World Wars, the need to see one's enemy as one fired began to wane but required better geographic information for success. Modern weapons can be aimed by relying on knowledge of the enemy's whereabouts using a geographic coordinate for his position. The requirement for mapping support for modern combat has changed dramatically, becoming vitally important to military personnel while at the same time introducing a potential source of confusion and error on the battlefield.

Geographic Location Issues on the Battlefield

Before long range weapons were refined, maps produced by each side could be used on the same battlefield since units joined in battle were within sight of each other. It didn't matter who had drawn the maps or which math model the mapmakers used to represent a round earth on a flat piece of paper because the range of weapons allowed one

to assume the battlefield was flat. Long range weapons however created a need to improve maps since the battlefield was becoming large enough to encompass entire countries. The increased requirements of weapon systems necessitated taking into account the curvature of the earth.[1]

While it is beyond the scope of this paper to detail the methods used to map the "round" earth on a flat piece of paper, we can explain the impact this topic has on modern combat. We will see that mapping concepts such as datums have a significant impact on the targeting of long range weapons. A datum is a geometric quantity which may serve as a reference or base for other quantities. Datums are used in map making by defining the following quantities:

1. Latitude/Longitude or elevation at the origin
2. Geoidal height (height above a equipotential gravity surface roughly approximated by mean sea level) at the origin
3. Semi-major and semi-minor axis of the reference ellipsoid to describe the shape and size of the earth.[2]

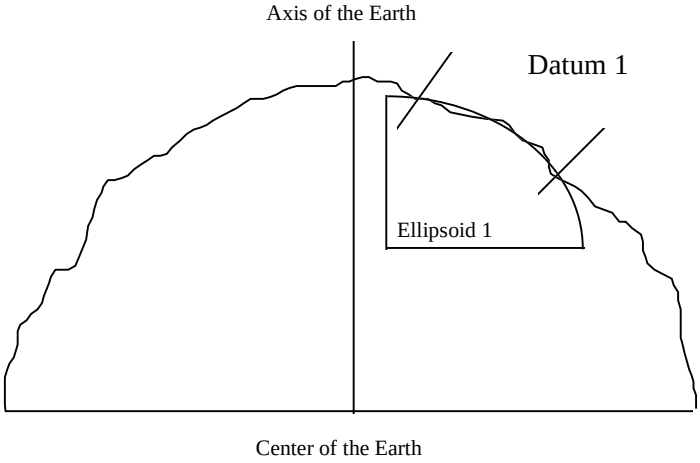
Datums can be defined for the horizontal component of a geographic coordinate (latitude and longitude) and for the vertical component (referred to as elevation).

World Wars and Local Datums

Cartographers during the period encompassing two World Wars used datums to describe the shape of the earth in their country's territory in order to make maps supporting the increased range of weapons. While these advances in mapping were very important, seldom was there any economic or military reason to share datums between countries.[3] However, the introduction of long range artillery like the railroad guns used by the Germans to fire shells many tens of miles soon illustrated that mapping differences

between countries could cause significant problems in military operations. Coordinates could not always be taken from one map and related to coordinates taken from a neighboring map.[4] The reason for this is based upon the datums used to make the maps.

Figure 1 shows how one country could develop a datum for mapping purposes using a portion of an ellipsoid to model the shape of the earth in their area. An ellipsoid is ". . . a model for the shape of the earth, defined in a way to illustrate the deviation of the earth from a true spherical form."[5] The portion of the ellipsoid coincident with the country's territory is used to plot the location of natural and man-made features in order to draw the map. This portion of the ellipsoid is referred to as a datum.[6][7]



Source*:* "*Geodesy for the Layman*." The illustrations of ellipsoids and datums shown here and further down in the text were constructed by the author but inspired by illustrations in Geodesy for the Layman

Figure 1. Using an ellipsoid and datum to model the earth

Another nearby country could develop a different ellipsoid and datum to represent the shape of the earth in their area (see Figure 2). Since these two datums are not the same, coordinates from the two maps can not be related directly to each other. To do so requires knowledge of the mathematical relationships between the two datums.

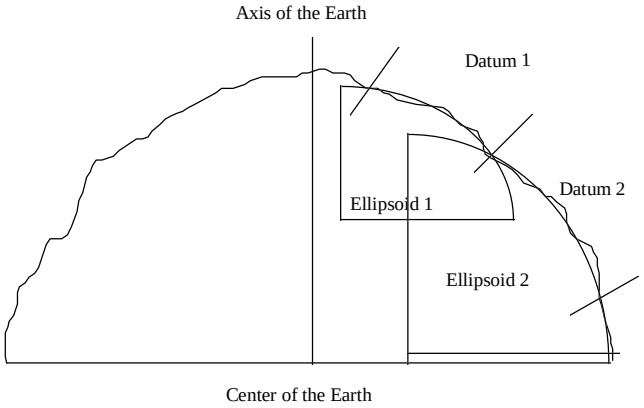


Figure 2. A nearby country uses a second ellipsoid for their local area

In this example, if the first country were to target the second country using geographic coordinates from their own maps of country two but based on datum 1, they would miss their target. This is because datum 1 does not describe the shape of the earth in country two. Plotting country two's features onto datum 1 would cause an error similar to that illustrated in Figure 3.

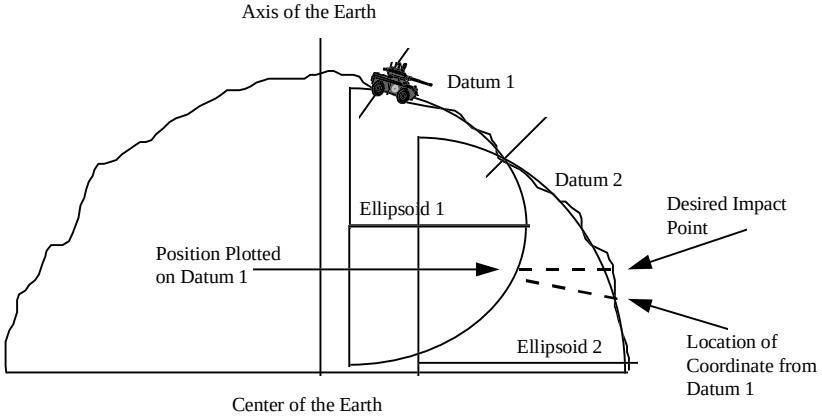


Figure 3. Error in geographic position extending one datum

If the first country were to capture maps from the second country and use coordinates from country two's maps for aiming their weapons, they still would not hit the intended target. This is due to the fact that coordinates for the launching point are not referenced

to coordinates for the impact point. Projecting the coordinates from datum 2 onto datum 1 would cause location error of more significant magnitude (see Figure 4).

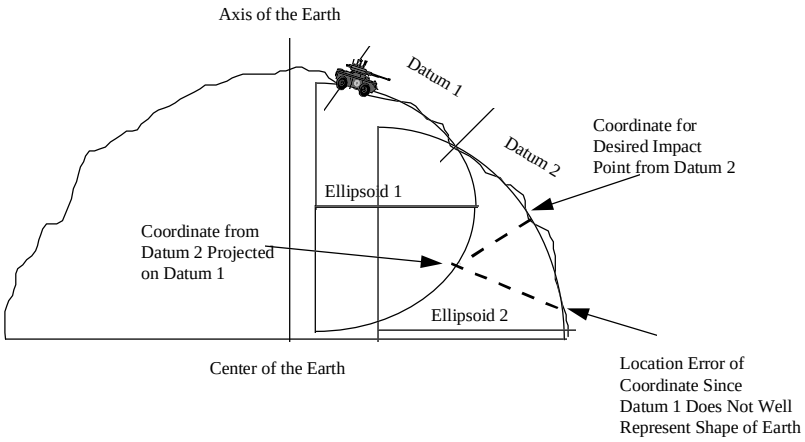


Figure 4. Error in geographic position due to mixed datums

These issues affected combat operations throughout the early half of this century. During World War II, the improper use of geographic coordinates and datums to which they were related caused weapons to go astray by as much as 1 mile.[8]

Ballistic Missiles and a Worldwide Datum

After World War II, the United States began development of very long range ballistic missiles which could be fired more than 5000 miles.[9] Small errors in aiming due to incorrect coordinates from different datums could cause a missile to hit far from the intended impact area. Keeping launch point and target coordinates relative to each other using the same datum was absolutely critical to success. Thus it became necessary to have one ellipsoid upon which to map the entire earth, using it as a single worlwide datum.

The Department of Defense developed the World Geodetic System (WGS) to allow maps of any place in the world to use a single common datum. The system consists of an ellipsoid with its mid point at the center of the earth and the mathematical shape described

to best represent the shape and size of the entire earth (see figure 5).[10] Even in areas where the match between the WGS datum and the shape of the earth is not especially good, the advantages of a single reference system for geographic coordinates outweigh the disadvantages in many circumstances.

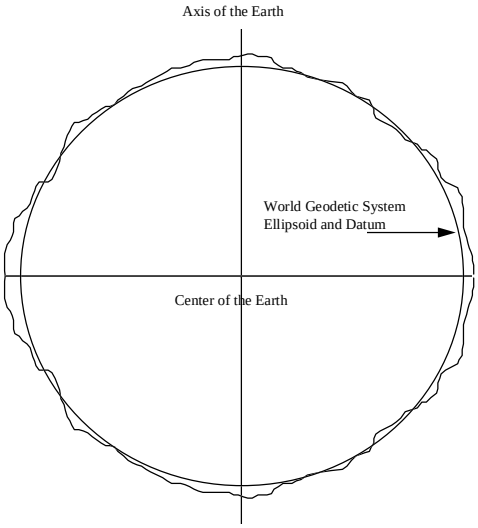


Figure 5. A single ellipsoid for the World Geodetic System datum

However, many countries without long range missile programs continued to use local datums for mapping purposes since they had no reason to switch to WGS. This was especially true for countries where WGS did not well represent the earth's shape in a local area. In some areas (like Korea), overlapping and adjacent maps currently in use can be found based on both WGS and local datums (such as the Tokyo datum). Figure 6 shows an example where coordinates for buildings at the adjoining edge of two adjacent map sheets are not the same due to different datums. The difference between the two sets of coordinates is 729 meters. Location problems due to different datums on adjacent or overlapping map sheets are not uncommon.[11]

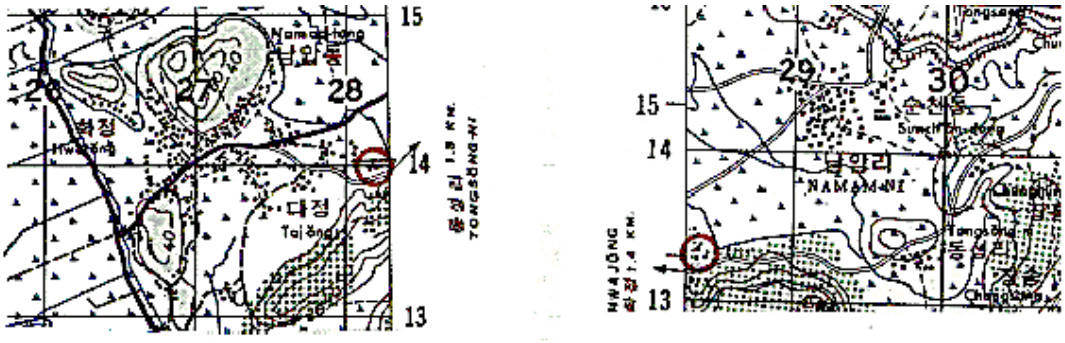


Figure 6. Adjacent maps using WGS-84 (left); Tokyo Datum (right)

Modern Weapon Systems Must Use Coordinates from a Single Datum

Development of precision guidance for conventional weapons and aircraft also came to fruition during the Cold War years through the application of advanced ICBM guidance technology onboard these platforms. Weapons with internal Inertial Navigation Systems (INS) or Global Positioning Systems (GPS) require information about where they are and the location of their targets. Geographic coordinates for these points are of primary importance when using these weapon systems. To avoid problems just discussed they must be based on the same datum. Laser- and optically-guided weapons are not dramatically impacted by geographic coordinates but the aircraft used to carry them to the fight are affected. This also is true of aircraft used to carry unguided munitions. In order to get any of these weapons to the target, we rely on navigation systems such as INS or GPS installed on board aircraft. These aircraft navigation systems will not work well without coordinates based on a single datum.[12] [13]

Navigation systems allow pilots to input into a flight computer coordinates for their starting point, enroute way points for the proposed route to the target, and the target or aimpoint. The computer then keeps the aircraft on course to the target and also feeds data to the targeting system. The targeting system allows the pilot to fly toward the target in

an attack profile, use the radar or some other system to identify the target or aimpoint, and release the weapons based on the calculated range and bearing between the points. Keeping the coordinates relative to each other by ensuring they are taken from the same datum is critical to this process.

Many military personnel are not aware of the important role datums play in coordinate systems.[14] Because coordinates are provided or acquired from many sources during combat operations, confusion and errors can easily be introduced into planning for and conduct of warfare, especially when coordinates based on different datums are intermixed. This problem worsens when planners and operators must deal with time limitations during crises in remote corners of the world. In the rush to identify, disseminate and use geographic coordinates, the datum from which they are taken often gets ignored.

Potential Confusion in Coordinate References

There are several hundred datums in use throughout the world providing a basis for coordinate reference systems on thousands of maps.[15] Lack of awareness concerning datums is one major source of confusion when using geographic coordinates and often stems from the fact that users are not aware of and do not cite the source of the coordinate they are using. They assume the coordinate they are using is compatible with others because they don't know what datum it is based on and it looks the same as any other coordinate they ever encountered.[16]

Operational Methods to Acquire Coordinates in the Air Force

An aviation unit tasked to perform combat operations has many alternative methods for acquiring coordinates for their intended targets. The Joint Force Air Component Commander (JFACC) or the air component commander apportion missions to be flown by publishing an Air Tasking Order (ATO). Sometimes the ATO will have the coordinates for the targets included. Sometimes the ATO will have only a reference number for the targets which will allow the units to look up pertinent information including target coordinates.

If the coordinates are included with the ATO, the unit next needs to develop a mission plan which will include navigation waypoints to and from the target as well as any necessary offset aimpoints in the target area for computer-aided or radar bombing. In order to do this, the unit may make use of equipment such as the Analytical Photogrammetric Positioning System (APPS). APPS provides coordinates suitable for targeting which are based on WGS. Though the system is old and slow and is being replaced, it still is used widely throughout the Air Force. The APPS has a program which can transform coordinates from WGS to any other datum and vice versa. Another source of coordinates is the Air Force Mission Planning System (AFMSS). AFMSS coordinates are meant primarily for navigation to and from the target and are obtained from computer imagery and digitized maps and are also in WGS.

If the ATO does not include target coordinates, and the units do not have access to the APPS or AFMSS machines (or the proper databases that cover the area of the world in which they are interested), then they must seek coordinates for waypoints, aimpoints and targets from other sources. One such source is the JFACC or air component

commander who originally sent the ATO. If the JFACC still can not provide the necessary information, then they often will "reachback" to intelligence organizations to acquire the needed coordinates. The theater's Joint Intelligence Center has a coordinate generation capability as does the National Imagery and Mapping Agency (known as NIMA and comprising the former DMA). All of these scenarios for acquiring geographic coordinates are highly dependent on proper communication of requirements for coordinates to the producing organization and communication of the results back down the chain of command to the unit involved.

Clarity and consistency are vitally important, especially since all coordinates for a single mission, including navigation waypoints, aimpoints and target coordinates, must be based on the same datum. Units often acquire coordinates based on different datums from these many sources without knowing it. If this happens the unit will develop a mission plan that is destined to fail.

Joint Operations Can Increase Confusion

NIMA has gone to great lengths to provide the best possible map products and other geographic data to military forces around the world. They often make use of bi-lateral and multi-lateral relationships with other countries to obtain maps, charts and geodetic products to supplement their own production. At times, the products they receive from these relationships are not based upon the WGS datum in use within the United States military. Potential for confusion over proper use of coordinates and datums increases during joint operations since the services often use different DMA products as part of their standard procedures.

Army and Marine ground units use maps to determine coordinates for Close Air Support and can easily introduce another datum into the targeting equation. This is especially true since they rely on 1:50,000 and 1:100,000 scale topographic line maps that may have been produced in nations that do not use WGS. Air forces use smaller scale aeronautical charts based on WGS. In addition, naval forces, especially naval air forces onboard carriers, use the APPS and automated mission planning systems in a fashion similar to the Air Force. Improper use of coordinates during planning on board carriers closely mirrors the Air Force's problems, especially if personnel do not recognize mixed datums and convert the coordinates to one datum. Communication problems between services and a reliance on message and voice communications to disseminate coordinates contributes to confusion since no service routinely provides information regarding datum with their coordinate references. By omitting or ignoring datum, improper use of coordinates can cause significant problems during military operations.

Notes

[1]Department of Defense. *Defense Mapping Agency Technical Report 80-003, "Geodesy for the Layman,"* Washington DC: Defense Mapping Agency, December 1983, 32.

[2]Department of Defense. *Glossary of Mapping, Charting, and Geodetic Terms* Fourth edition. Washington, DC: Defense Mapping Agency, 1981, 43.

[3]Heller, Waren G. and LeShack, A. Richard. *Military Geodesy and Geospace Science, Unit Two*. Hanscom AFB, MA: Air Force Geophysics Laboratory, February 1981, 1-79.

[4]Miller, Henry W., Lt Col. *The Paris Gun*, New York, NY: Jonathan Cape and Harrison Smith, 1930, 86-89.

[5]*Glossary of Mapping, Charting, and Geodetic Terms*, 53 and 166. This definition combines the definition for ellipsoid and the definition for spheroid, two terms used interchangeably.

[6]*"Geodesy for the Layman,"* Washington DC: Defense Mapping Agency, December 1983. The descriptions of ellipsoids, datums, and map making in this and the next few paragraphs draw heavily from Geodesy for the Layman and World Geodetic System, 1984.

Notes

[7]Department of Defense. *DMA Technical Report 8350.2, World Geodetic System 1984*.

[8]Wallace, John B., Colonel *An Examination of Geodetic Data Problems Related to Long-Range Guided Weapons (U).* Maxwell AFB, AL: Air University, April 1954, 3. (Confidential) Information extracted is unclassified.

[9]Ibid., 8.

[10]*DMA Technical Report 8350.2, World Geodetic System 1984*

[11]Department of Defense. *Defense Mapping Agency Pamphlet, "These Warfighters are Ready for Combat...,"* Washington DC: Defense Mapping Agency, 1994, 3.

[12]Dargan, John L., Captain *Autonomous Weapon Guidance.* Eglin AFB, FL: Wright Laboratory, May 1994, 15.

[13]Frost, Gerald. *Operational Issues for GPS-Aided Precision Guided Weapons.* Santa Monica, CA: RAND, 1994, v.

[14]Macy, Richard V. Air Combat Command, phone interview by author, 15 Jan 97.

[15]*DMA Technical Report 8350.2, World Geodetic System 1984*, 7-1.

[16]Macy, Richard V. Air Combat Command, phone interview by author, 19 Feb 97. The following discussion concerning operational methods to acquire coordinates is based loosely on information provided by Mr Macy.

Chapter 3

Operations Review

Everything is very simple in war, but the simplest thing is difficult

—Carl Von Clausewitz

As a way of illustrating the importance of geographic location during times of war we will now examine several recent United States military operations with an eye toward learning lessons for future military planners and operators. We will find that two operations, Urgent Fury and Eldorado Canyon suffered from mistakes associated with geographic location while these issues were not as prevalent in Operations Just Cause and Desert Storm. While the use of coordinates was satisfactory in Just Cause and Desert Storm, will we be able to ensure conditions that led to this success will occur again in future conflicts?

Real World Problems

The first two operations we will look at can be thought of as rather similar in two ways, both were rapid responses to fast breaking national emergencies. Under these conditions, crisis action procedures, operational confusion, and the fog of war often get the better of military forces and subsequent mistakes with geographic coordinates caused significant problems. Because datum was not included with coordinate references, military

personnel mixed coordinates from different datums and negatively impacted conduct of operations

Urgent Fury

Operation Urgent Fury was the code name for the liberation of US medical students in danger on the island of Grenada due to Maurice Bishop and the Marxist government he installed during September and October 1983. Because of the fast paced events on the island, the United States originally planned for a Non-Combatant Evacuation Operation. However, due to unrest in Grenada and the violence that followed, the operation became an air assault to control the island and rescue US citizens. A complicating factor in planning the operation was the sense of secrecy US planners invoked, restricting knowledge of the operation to very few personnel. This led to serious consequences in the mapping support provided by Defense Mapping Agency and the Army's topographic unit involved.[1]

Because the nature of Operation Urgent Fury changed to a "come as you are" operation involving all five services in a very short time, no one checked to see if adequate map and chart coverage existed over the area. US interests in Grenada had been very benign up to this point in history and few US resources were expended in mapmaking prior to the start of the operation. The level of operational security imposed did not allow any time for production of military maps of Grenada once DMA was apprised of potential combat in the area. One very good British Military Survey map existed, but it had been converted into a tourist map by adding fancy borders and information about points of interest. This map was used during the planning leading to the invasion.

The British Military Survey map used a local datum, the Universal Transverse Mercator projection and a grid system divided into 2000 meter squares. Similar United States military map products use WGS and the Military Grid Reference System (MGRS) also is based upon UTM but is divided into 1000 meter grid squares. This caused a great deal of confusion. Unfortunately, an Army topographic unit contributed to the confusion by reproducing the excellent base map from the British Military Survey but they applied their own arbitrary MGRS-like grid. They used letters and numbers for the grid much like an atlas would (e.g., A-Z in the horizontal edge of the grid, 1-20 along the vertical edge of the grid). Later, the Defense Mapping Agency produced a standard topographic line map commonly used by US military forces. When they did this, they rushed it to the theater thereby introducing yet another map into the already confused combatants' hands.[2]

During combat operations, use of these maps caused several mistakes during missions where close air support, artillery fire and helicopter landings were to occur on certain coordinates. None of the units involved were aware of the problems associated with mixed use of coordinates and datums before or during the operation. While the operation was a success, the confusion caused by mixed coordinates and datums had a negative impact on operations. These mistakes could have been avoided if anyone involved in planning and executing the operation had recognized the problem. Since coordinates were disseminated from the many sources without citing additional information to identify the datum or source of coordinates used, this could not occur.

Eldorado Canyon

Another rapid reaction operation was Eldorado Canyon. In the days leading up to this operation, the United States was able to assign responsibility to Libya for the Berlin

disco bombing which killed and wounded US servicemen on 5 April 1986. The US retaliated against Libya's sponsorship of such acts by launching air raids on Libyan facilities supporting terrorist training activities.

Prior to Eldorado Canyon, freedom of navigation operations were conducted by US Navy assets in the Gulf of Sidra. These were strictly carrier operations which resulted in the shooting down of Libyan MiGs and destruction of several radar stations. However, Eldorado Canyon planners determined that carrier aviation alone was insufficient for the desired response to the Berlin disco bombing. During the subsequent planning for the operation, Air Force F-111s from RAF Mildenhall in the United Kingdom were added to the Navy strike force. Compressed timelines, multiple chains of command, and operational security led to much confusion during planning for the raid. In this case, planning took place over a period of weeks with the air raid occurring within two weeks of the disco bombing. Since the Reagan administration wanted to make sure they were hitting targets associated with terrorism, targets shifted quite frequently and conflicting coordinates were disseminated. Once the targets were finalized, other problems associated with geographic location occurred.[3]

Eighteen Air Force F-111s took part in Eldorado Canyon and 17 attacked their targets. Of these, several did not release their weapons due to strict rules of engagement that required pilots to be certain of target identification before releasing their weapons. Although there were several hits from the F-111s almost one third of the planes that dropped bombs missed badly due to "…incorrect coordinates of an island update point…".[4] In this case, the target coordinates were provided to units by higher headquarters planners and were based on the European Datum. Unfortunately, the

"update points" and other aimpoints used during the mission were derived by the Air Force F-111 unit using the APPS and were based on WGS. The difference between the two datums used in this part of North Africa is several hundred meters.

While some F-111s were badly out of position due to this error, some planes still hit the targets because they were close enough to use their laser targeting systems effectively. By not including the datum with any of the myriad coordinate references during planning for Eldorado Canyon, military personnel caused the unenviable results obtained by the F-111s by not recognizing and converting coordinates from different datums.

Using One Datum

The late eighties and early nineties have been marked by two large scale operations involving large military air, ground, and naval forces. As one might expect, both of these operations were executed with a great deal of planning and preparation. As the entire US defense apparatus mobilized to support these operations, security and timelines allowed mapping personnel to participate in preparations. Consequently, problems with mapping support and the improper use of coordinates due to mixing of datums were mitigated. A vast array of weapons systems were used during the next two operations to be described. While laser- and optically-guided bombs received much attention during these operations, the majority of weapons used were conventional and benefited from the proper use of coordinates and datums. Even though datums were not cited with coordinate references, operations were successful since personnel ensured all mapping products used were based on WGS.

Just Cause

The US intervention into Panama in 1986 resulted from a long history of events which can not be adequately chronicled here due to space limitations. Suffice it to say that US relations with Panamanian leader Manuel Noriega slowly spiraled toward confrontation which led to the US intervention to protect United States citizens and property and to replace Noriega by installing the popularly elected government of Guillermo Endara. When this happened, Noriega and his henchmen in the Panamanian Defense Force resisted. Overwhelming US force was able to achieve all mission objectives including the capture of Noriega and his return to the United States to face criminal drug trafficking charges.

Planning for Just Cause was a long and drawn out course of events that proceeded for more than a year and a half from February 1988 until the invasion began in December 1989. Because the Defense Mapping Agency maintained a satellite office in Panama during this time, all necessary map products were either new or updated within the five years leading up to the invasion. Standard products with coordinate systems based on WGS were available throughout operation Just Cause. In fact, forces were able to rehearse actual missions in advance with the mapping products they later would use in the operation. This ensured a single datum was used for all coordinate references.[5]

Desert Storm

Operation Desert Storm was the US-led coalition response to Iraq's invasion of Kuwait in 1990. After rushing small numbers of troops, naval assets and fighter squadrons to defend the Kingdom of Saudi Arabia in the immediate aftermath of Iraq's invasion, planning shifted to a large-scale offensive to retake Kuwait. When negotiations

and sanctions failed to cause the Iraq's withdrawal, the US-led coalition invaded. A crucial part of this campaign was gaining air superiority over the huge Iraqi military and then wearing down their fielded forces and other key centers of gravity through air attacks prior to a ground assault. During the air campaign, large numbers of Precision Guided Munitions (PGMs) were used to ensure targets were hit and destroyed, even doing so in populated areas with minimal collateral damage. The PGMs used were primarily laser- and optically-guided weapons that required a man-in-the-loop to ensure the weapon hit its target.

Many more tons of unguided bombs were dropped using computers and radar bombing based on coordinates for targets and aimpoints.[6] Because US forces and support elements were geared up to provide everything necessary to prosecute the war, the Defense Mapping Agency became part of an elaborate reachback system that provided more than 8000 coordinates based on the WGS datum for on-going operations involving conventional bombing.[7]

The crisis began on 2 August 1990 and the air war did not begin until 15 January 1991 after many months of training and rehearsals. In the nearly six months of preparation, the Defense Mapping Agency was able to build map products that were not available in August 1990. For instance, Point Positioning Databases, used with the APPS by units in the field to generate precise geographic coordinates, did not exist in much of the area since US Central Command's focus had been oriented towards other countries in the region. Yet DMA was able to produce APPS databases and a vast array of other mapping products based on WGS for the Kuwait Theater of Operations before operations

began.[8] This consistency on the battlefield prevented problems with mixed coordinates and datums.

Desert Storm's success at using coordinates properly for bombing with unguided munitions has been overshadowed by publicity of the success of laser- and optically-guided PGMs. This has contributed to the perception that these weapons will always be available, ready for use, and successful in future conflicts. This may or may not be true since future combat operations are not likely to be conducted in an environment as favorable to laser and optical equipment as the desert. We may have to rely primarily on weapons that need coordinates based on a single common datum to be successful.

What's next?—Applying Lessons Learned

The lessons learned from the preceding review of recent military operations leads to a straightforward conclusion. The datum to which coordinates are referenced is crucial to combat success and military personnel need to be aware of the datum to which coordinates are referenced. Because personnel do not always pay attention to this important piece of information, especially during time of rapid reaction to fast-breaking crises, planners and operators are subject to confusion and errors.

It is difficult to predict what type of operations US military forces will be called upon to execute in the future but one may expect that most will be Military Operations Other Than War such as the on-going peace enforcement operations in Bosnia-Hercegovina and Haiti. Humanitarian assistance operations like the proposed 1996 operation in Rwanda also are very likely in the next ten to twenty years. In most cases, the need for these types of operations springs forth very quickly in the international and domestic political arenas.

Planning and preparations are more likely to be similar to those rapid reactions carried out during Urgent Fury and Eldorado Canyon. A method to ensure proper use of coordinates either during crisis response or during more deliberate planning is vital.

Notes

[1]Paton, Clark A. "A comparitive Analysis of Joint Intelligence Problems Encountered in Operations Urgent Fury and Just Cause." Monterrey, CA: Naval Post-Graduate School, September 1990, 28, 29, 59. (Secret) Information extracted is unclassified.

[2]US Atlantic Command. *Operation Urgent Fury Report.* Norfolk, VA: USCINCLANT, February 1984, 4.

[3]Tibeu, Paul, Lt Col, Moberly, Robert, LTC, and Murphy, John, Lt Col. "Force Projection: Seeds for a new Doctrine." Columbus, OH: Ohio States University Mershon Center, May 91, Draft, 105-107.

[4]Hoyes, Michael B. "Eldorado Canyon: Countering State-Sponsored Terrorism from the Air." Maxwell AFB, AL: Air University, March 1995, 46.

[5]Riley, Susan A. "Mapping, Charting and Geodesy Requirements for Military Contingency Operations." Fort Leavenworth, KS: Army War College, 10 April 1992, 12.

[6]US Government Accounting Office. *Operation Desert Storm, An Evaluation of the Air War.* Washington, DC: Government Printing Office, 1996, 17, 26.

[7]Anderson, Gregory S. "Charting the Storm, DMA's Role in Operation Desert Shield and Desert Storm." Newport, RI: Naval War College, 19 June 1993, 10. (Secret) Information extracted is unclassified.

[8]Ibid., 11, 13.

Chapter 4

Toward a Standard Geographic Coordinate Reference

Ignoring the fine print in the margin of the map could get you killed

—Defense Mapping Agency

No standard method now exists for overcoming potential confusion when using geographic coordinates since military personnel routinely ignore any reference to the datum from which they came. Indeed, many individuals fail to recognize a problem even exists when using coordinates from different datums.[1] A method to ensure proper use of coordinates is necessary to make identifying, disseminating, and use of coordinates during planning for and conduct of warfare more consistent and reliable. By mandating the inclusion of datum with every coordinate reference, we could eliminate one source of error on the battlefield. The standardized process must be documented in all relevant Joint Staff publications to ensure all services comply in a common fashion.

Recent Guidance on Use of Coordinates

Written guidance to help military personnel recognize and correct problems associated with mixed coordinate datums is too often restricted to the mapping and intelligence communities within the Department of Defense. The guidance that currently exists stemmed from actions taken during the post-Eldorado Canyon timeframe but has

been overshadowed by the success of Just Cause and Desert Storm. Efforts in the 1990s to produce guidance on the use of coordinates and datums is now encompassed in the attempts to capitalize on the joint warfare approach of a post-Desert Storm military by documenting joint doctrine and procedures. However, these efforts have failed to consistently put forward a standard method for overcoming problems with mixed datums.

Defense Mapping Agency

After Eldorado Canyon, the Defense Intelligence Agency and the Defense Mapping Agency conducted a joint working group to determine ways to better educate military planners and operators on the importance of datums to the proper use of geographic coordinates.[2] This working group developed a wall chart which was widely disseminated and explicitly called for users to always check the datum to which coordinates were related. This period also marked a effort by DMA to aggressively market its products and procedures for properly using them. In terms of coordinate guidance, DMA produced several video tapes and pamphlets designed to educate military personnel on the importance of datums.

The videotape "Your Target is. . ." and the pamphlets "These Warfighters are Ready for Combat…" and "Vertical Datums, Elevations, and Heights" did a good job educating some military personnel on the importance of datums. But this video and the pamphlets did not carry the force of a joint standard and had no means to enforce their recommendations upon the various sectors of the military. Also, none of these efforts provided a common, standardized way to approach solutions to the problem described.

By the early 1990s, with the advent of GPS and the success of laser- and optically-guided bombs in Just Cause and Desert Storm, many personnel now assume that problems

with datums have gone away. Potential is still very high for problems to be encountered with coordinate datums during rapid responses to crises. This is especially true if the crisis occurs where there are non-standard mapping products based on a datum other than WGS.

Joint Staff Publications

More than 75 joint publications were reviewed using the Joint Electronic Library CD-ROM, dated September 1996, for doctrine and procedures related to the proper use of datums and coordinates. Most of these publications mention mapping support in only the broadest terms. This seems appropriate for keystone documents like Joint Publication 2-0, "Doctrine for Intelligence Support to Joint Operations" and Joint Publication 3-0, "Doctrine for Joint Operations." However, more detailed publications aligned under the keystone documents which contain specific doctrine and Joint Tactics, Techniques, and Procedures (JTTP) for the conduct of military operations should cover this subject in depth.

Four of the detailed doctrinal publications and JTTPs mention geographic datums by name. Only two of these documents cover the proper use of coordinates and datums in any degree of detail. Joint Publication 3-09.2, "JTTP for Radar Beacon Operations," 23 April 1996 and Joint Publication 3-09.3, "JTTP for Close Air Support (CAS)," 1 December 1995 both do so but only the former specifically states that "[w]hen identifying position coordinates for joint operations, it is imperative to include the map datum that the location coordinates are based on" since they may come from "…several different datum bases."[3] The latter publication states that inclusion of datum with coordinate references is optional, saying "[e]veryone in the joint CAS process must use a common datum as

established by the JFC. Should the JFC not designate a standardized datum, or if there is any doubt as to which datum is being used, requesters of CAS should specify the datum…"[4]

The other two publications, 3-05.5, "Joint Special Operations Targeting and Mission Planning Procedures," 10 August 1993 and 3-07, "Joint Doctrine for Military Operations Other Than War," 16 June 1995 specify that datum should be included when identifying, disseminating or using coordinates. These publications do not describe why this is so but simply state that ". . . it is essential that maps, charts, and support data (to include datum and coordinate system to be used) are coordinated in advance."[5]

These statements contribute to confusion when military forces use coordinates and datums because there is no standard way for handling this information. The JTTP for Targeting Support to Joint Operations and the JTTP for Mapping, Charting, and Geodesy (MC&G) Support to Joint Operations have yet to be published but could initiate a standard method for including datum with all coordinate references. Conversations with the Command Cartographer, Air Combat Command state that the initial drafts of these publications did not contain any such proposal.[6] The standard proposed below for inclusion into these JTTPs should then be included in the many other joint publications in exactly the same manner.

A Modern Coordinate Reference

Military personnel using coordinates should ensure datum is always associated with geographic coordinates to prevent one source of confusion and error on the battlefield.

Coordinate and Datum Cited together

All references to geographic coordinates should contain the following five elements. The reference should include latitude, longitude, horizontal datum, elevation, and vertical datum. As an example, one could cite:

37 45 16.45N 105 15 23.30W WGS-84 1650ft NGVD

where the first two field are the latitude and longitude, the third is the horizontal datum, the fourth is the elevation, and the fifth field is the vertical datum. Most military personnel already use latitude and longitude along with hemisphere references and units of measure for elevation. By adding the datum, military personnel now can determine whether a coordinate is from the same references system as others he is using.

Eldorado Canyon Revisited

If military personnel in various headquarters in the United States, Europe, at sea on board aircraft carriers, and at Air Force bases in England had included datum with every coordinate reference during planning for Eldorado Canyon, the results of the bombing would have improved dramatically. Since the "island update" point was derived from an APPS machine and was based on WGS and the target coordinates were provided to the units from higher headquarters but were based on the European datum, many bombs missed their targets. If the datum had been included with the coordinates for the target when it was disseminated, planners and operators at the units would have been able to recognize that they needed to convert the target coordinate to WGS to be consistent with the coordinates in the mission plan.

Notes

[1]Macy, Richard V. Air Combat Command, phone interview by author, 15 Jan 97.

[2]Riley, Susan A. "Mapping, Charting and Geodesy Requirements for Military Contingency Operations." Fort Leavenworth, KS: Army War College, 10 April 1992, 31.

[3]Department of Defense. *Joint Publication 3-09.2, "JTTP for Radar Beacon Operations*," Washington, DC: Joint Staff, 23 April 1996, III-1.

[4]Department of Defense. *Joint Publication 3-09.3, "JTTP for Close Air Support (CAS),"* Washington, DC: Joint Staff, 1 December 1995, IV-6.

[5]Department of Defense. *Joint Publication 3-07, "Joint Doctrine for Military Operations Other Than War*," Washington, DC: Joint Staff, 16 June 1995, IV-3.

[6]Macy, Richard V. Air Combat Command, phone interview by author, 19 Feb 97.

Chapter 5

Conclusion

> *Advances in computer processing, precise global positioning, and telecommunications will provide the capability to determine accurate locations of friendly and enemy forces, as well as to collect, process, and distribute relevant data to thousands of locations.*
>
> —General John M. Shalikashvili
> Chairman, Joint Chiefs of Staff

General Shalikashvili's quote at the beginning of this chapter hints at the accomplishments possible by recent advances in weaponry and the support they receive. However, if datum is not included with geographic references, the potential for failure is high since a key piece of information will be missing at "thousands of locations."

This paper showed that location is often an issue in combat, from ancient times until today. As technology increased the range at which one may engage an enemy, correctly locating oneself and one's target became critical. Long range artillery in World War I and other weapons in World War II required knowledge about the shape and size of the earth and the datums upon which maps were based. Merely providing geographic coordinates as a means of location was no longer sufficient during modern combat and continued to be an issue in more recent operations.

Operations Urgent Fury and Eldorado Canyon showed how confusion over coordinates and missing information regarding the datum to which a map coordinate was

referenced caused problems during combat. One major reason for this confusion stemmed from little time to adequately plan mapping support for combat. Later operations such as Just Cause and Desert Storm suffered little from confusion over coordinates and datums largely because there was enough time to prepare for combat and multiple datums were eliminated by using a single reference system for all coordinates in theater.

Recent efforts to educate military personnel on the importance of datums has been relatively ad hoc and not directive in nature. The program to develop joint doctrine publications provides an outstanding opportunity to rectify this situation but action must be taken to make a common, standard coordinate reference, which includes the datum, a requirement for all joint military operations. The JTTP for Intelligence Support to Targeting (2-01.1) and the JTTP for MC&G Support to Joint Operations (2-03) currently being drafted must ensure a standard method for referencing coordinates that includes datum is published, not only in these publications but consistently across the entire spectrum of more than 70 documents. While the joint staff is responsible for this process, National Imagery and Mapping Agency personnel could also ensure the standard coordinate reference is placed in the other joint publications during the coordination and review process while staffing the documents. The information provided in these documents must be consistent across the entire spectrum of documents rather than the "hit-or-miss" information currently provided in some keystone documents and JTTPs.

The increased range of modern weapons provide an highly effective warfighting capability to military forces. To work properly, they require more than just geographic coordinates to ensure that friendly forces know where they are and where the enemy is.

The datum to which coordinates are referenced is now an essential piece of information that must be included when identifying, disseminating or using geographic coordinates.

Glossary

AFMSS	Air Force Mission Planning System
APPS	Analytical Photogrammetric Positioning System
ATO	Air Tasking Order
CAS	Close Air Support
CD-ROM	Compact Disc - Read Only Memory
DESERT STORM	Coalition effort to eject Iraq from Kuwait, 1990-91
DMA	Defense Mapping Agency (now part of NIMA)
ELDORADO CANYON	United States reprisal strike against Libya, 1986
GPS	Global Positioning System
INS	Inertial Navigation System
JFACC	Joint Forces Air Component Commander
JFC	Joint Force Commander
JTTP	Joint Tactics, Techniques, and Procedures
JUST CAUSE	United States invasion of Panama, 1989
MC&G	Mapping, Charting, and Geodesy
MGRS	Military Grid Reference System
NGVD	National Geodetic Vertical Datum
NIMA	National Imagery and Mapping Agency
PGM	Precision Guided Munition
URGENT FURY	United States invasion of Grenada, 1983
UTM	Universal Transverse Mercator
WGS	World Geodetic System

datum. A geometric quantity which may serve as a reference or base for other quantities. Used in map making by defining five quantities to describe the shape and size of the earth and using this as a basis for mapping. The five quantities used are Latitude, Longitude, and geoidal height (height above a equipotential gravity surface roughly

approximated by mean sea level) at the origin, and the semi-major and semi-minor axis of the reference ellipsoid.

ellipsoid. a model for the shape of the earth, defined in a way to illustrate the deviation of the earth from a true spherical form.

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